SLA-1

King County Airport
Turf Enhancement

Sludge Land Application Project

METRO

Work Plan

March 1981

Municipality of Metropolitan Seattle

Copy 1 2100

METRO LIBRARY
MUNICIPALITY OF METROPOLITAN SEATTLE
821 SECOND AVENUE
SEATTLE, WA 98104

THE KING COUNTY AIRPORT
TURF ENHANCEMENT PROGRAM

By

Kevin Mayer

Water Quality Division

FOR LIBRARY
USE ONLY

METRO LIBRARY
MUNICIPALITY OF METROPOLITAN SEATTLE
821 SECOND AVENUE
SEATTLE, WA 98104

ABSTRACT

The King County Airport Turf Enhancement program report is the workplan for the sludge utilization project at the King County Airport (Boeing Field), designed to enhance the turf around the runaways. The workplan explores environmental and public health effects, and presents a nitrogen budget for the project. The monitoring effort, application method, responsibilities and scheduling are discussed.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the generous assistance of the Metro staff and other colleagues in the preparation of this document. In particular:

- Mark Lucas and Charles Nichols developed the initial outline of this work plan, gathered information and provided criticism and direction throughout the project.

- Lloyd Egan of Metro's Water Quality Enhancement Section and Gunar Sreibers of the Facilities Planning Section patiently assisted in determining the impacts on the Duwamish Estuary.

- Jeff Winter, Jack Frazelle and Duaine Moe of the King County Airport were most helpful in answering specific questions about the site.

- Drs. Kriistina Vogt, Bob Edmonds and Dale Cole of the University of Washington supplied essential data and advice.

- Stew Messman of the Department of Ecology and other staff from the DOE and Corps of Engineers provided important insights and information.

Table of Contents

SUBJECT	PAGE

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The King County Airport Turf Enhancement Sludge Application program is a Metro funded project which utilizes municipal sewage sludge at the King County Airport (Boeing Field). The project is designed to enhance the turf around the runways (for safety and aesthetics) as well as to provide more precise data on nitrate loss to surface and groundwater as part of a major monitoring effort.

The airport is in the industrial Duwamish River Valley, on a flat site (5% grade) with well drained, sandy soil. There is no groundwater usage in the area. Since the Duwamish River Estuary is approximately 1,500 feet from the airport and remains tidal (with a sub-surface saltwater lens) for several miles upriver from the site, groundwater in the area should never be a domestic water source.

At a one inch application rate (20 dry tons per acre), odors and surface runoff will be minimized. Public health risks from water or airborne pathogens also appear to be negligible. Previous research shows that possible leaching of nitrate from the site will be the only source of potential environmental concern (Edmonds and Cole, 1977).

Of the 1,400 lbs. nitrogen (N) per acre applied (20 dry tons sludge/acre at 3.5 percent N) only 21 to 34 lbs. N/acre will be released to the rooting zone per year. Grass uptake is 150 to 300 lbs. N/acre annually, so no N is expected to be leached from the site.

An intensive monitoring effort will quantify a complete range of environmental parameters in sludge, soil and drainage water.

Implementation of the project is scheduled for April, 1981. Application sites will be clearly marked, as will a 5 foot buffer strip around each surface drain. Five truckloads of sludge per day (weekdays only) will be delivered by Metro and spread to a one inch depth by airport personnel on the same day as delivered. The airport's 24-hour security patrol will prohibit public access to the site, and the airport will continue its surveillance for bird hazards in compliance with FAA regulations.

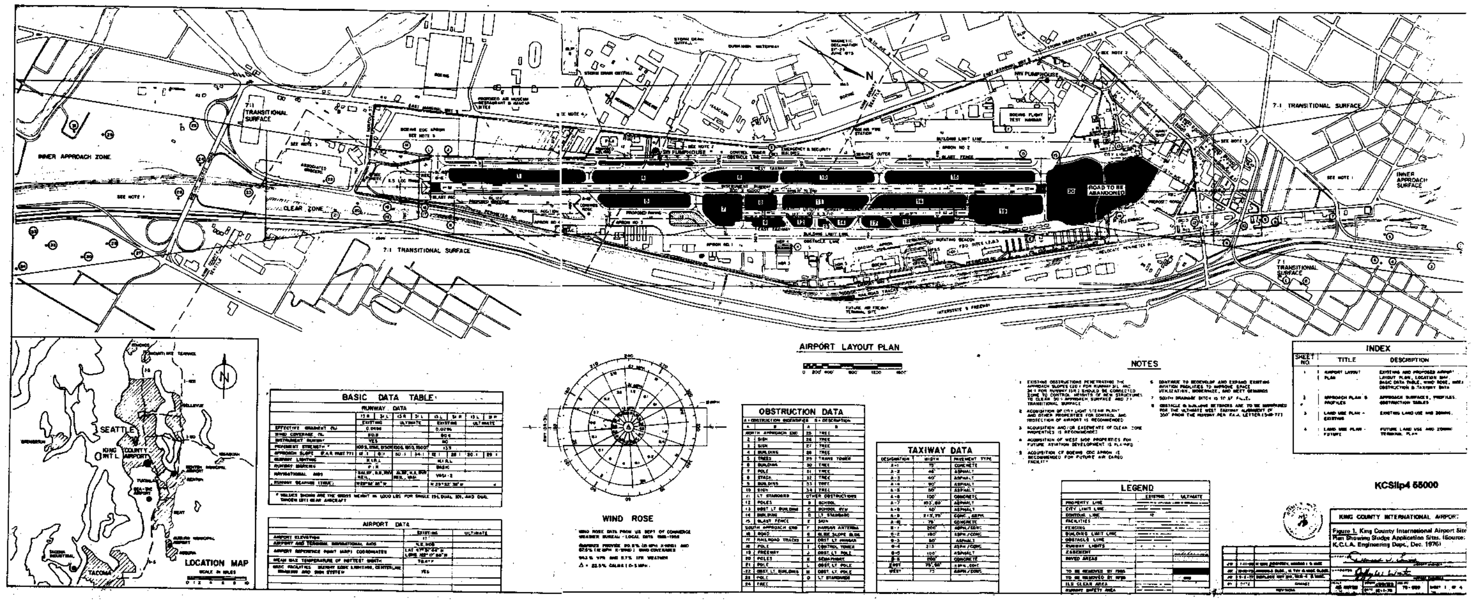
INTRODUCTION

The King County Airport Turf Enhancement Sludge Application program is a Metro funded project undertaken at the request of airport officials concerned with improving airport turf conditions which had developed into a potential safety hazard for aircraft. In addition to the concerns of the airport officials, Metro was concerned that stormwater, which collected and drained into the Duwamish River, could pose an environmental hazard. This project also would provide a site for an intensive monitoring effort which would enable Metro to quantify the impact of storm runoff. Information from this project will be useful for Metro's future sludge utilization planning.

BACKGROUND

The King County International Airport (Boeing Field) ranks within the top 20 airports in the country in the number of takeoffs and landings per year. Private aircraft account for most of the traffic, and commercial use is relatively light (personal communication from airport personnel).

The airport straddles the Seattle-King County boundary line in the Duwamish River Valley. Although the Duwamish once meandered through the site, channelization and filling operations around the turn of the century removed the waterway to over 1,500 feet from the airport (Figure 1). The present Seattle city limit follows the former channel.



KCSIlp4 55000

Figure 1. King County International Airport Site Plan Showing Sludge Application Sites. (Source: K.C.I.A. Engineering Dept., Dec. 1976)

SEA421328

DISCUSSION

SITE DESCRIPTION

The King County Airport

The King County Airport covers a total of 585 acres. Most of the airport lies within the southern boundary of Seattle, with the remainder in unincorporated King County. The city limit meanders through the airport.

The airport site is oriented from the northwest to the southeast (approximately 30° west of north), paralleling railyards and Interstate 5 to the northeast and Marginal Way to the Southeast (see Figure 1). Albro Place South and Ellis Avenue South form the northwest boundary and South Norfolk Street is the southern limit of the airport.

Duwamish Valley

The Duwamish Valley is a major industrial area with such firms as Kenworth Truck Company, Isaacson Steel and The Boeing Company immediately adjacent to the airport along Marginal Way. The Georgetown residential area is located to the northwest of the airport and currently has zoning limitations (Figure 2). Buildings owned by the King County Airport and Seattle City Light are interposed between the project sites and these commercial/residential areas. A Zellerbach Paper Company Building, the railroad tracks and I-5 are confined by the steep eastern wall of the valley. An Associated Grocers warehouse is located on the adjacent property to the south.

Sludge Application Plots

The sludge application plots lie within the security perimeter of the airport and are almost completely surrounded by airport offices, hangers and businesses. The southern boundary is not confined by airport buildings; however, no sludge will be applied within 1,500 feet of this boundary.

Twenty separate areas totalling 108 acres are proposed for sludge application (Figure 1). These range in area from 0.7 to over 26 acres. Only the northernmost area is greater than 10 acres. All are grassy plots between runways and taxiways. Sludge will not be applied over the abandoned road through the northernmost area.

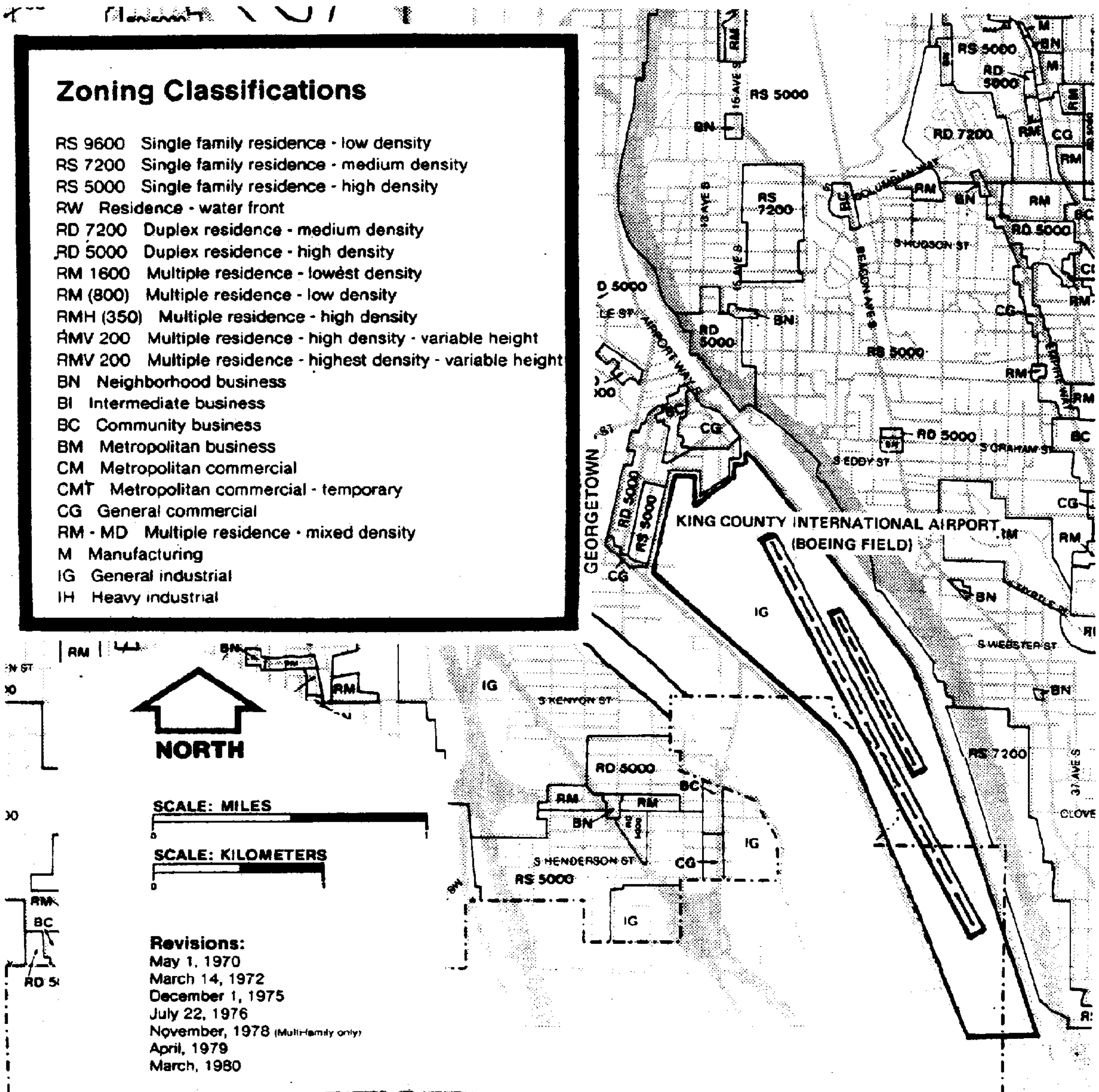


Figure 2. Zoning Restrictions in Airport Vicinity
(Source: City of Seattle Zoning Map, April, 1980)

ENVIRONMENTAL CONDITIONS

Precipitation

The average monthly precipitation data for the King County Airport and nearby recording stations (Table 1), show that 75 percent of the annual precipitation falls from October through March. Dry conditions predominate in the summer months.

Monthly, annual and daily extremes of precipitation for the Seattle City Station (Table 2), further illustrate the seasonal differences in this region. Note that during the summer months, daily rainfall has never exceeded 1.91 inches.

Evapotranspiration measured at the University of Washington (Table 3), indicates that excess precipitation falls in the winter months recharging the groundwater. There is insufficient rain during the dry season to permit maximum evapotranspiration; hence water, stored in the surface horizons of the soil, becomes severely depleted. Individual storms during the summer may be intense enough to temporarily overcome the deficit, resulting in some loss to the groundwater.

Table 1. AVERAGE MONTHLY AND ANNUAL PRECIPITATION (Inches)

Station	Elevation	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Seattle Boeing Field	14	5.46	4.21	3.53	2.15	1.58	1.43	.66	.81	1.83	3.50	5.22	5.73	36.11
Seattle City	14	5.19	3.90	3.32	1.97	1.59	1.41	.63	.74	1.65	3.28	5.00	5.42	34.10
Seattle-Tacoma Airport	386	5.73	4.24	3.79	2.40	1.73	1.58	.81	.95	2.05	4.02	5.35	6.29	38.94
Seattle U of W	112	5.02	3.93	3.28	2.16	1.84	1.62	.74	.75	1.72	3.42	5.01	5.47	34.96

Source: Brown and Caldwell/Jones and Jones, 1979.

Table 2. PRECIPITATION EXTREMES (Inches)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Seattle City													
Greatest mo. & annual	10.93	6.92	7.23	4.56	4.67	3.35	1.88	2.03	3.46	7.43	9.40	15.33	46.95
Least mo. & annual	1.43	1.29	1.22	.16	.35	.17	T	T	.12	.80	1.04	1.00	19.52
Greatest daily	2.46	2.69	2.32	1.53	1.35	1.08	1.22	.79	1.91	1.97	3.20	3.31	3.31
Seattle-Tacoma Airport													
Greatest mo. & annual	12.92	9.11	8.40	3.75	4.76	3.90	2.10	2.18	4.60	8.95	9.69	9.50	55.14
Least mo. & annual	.86	1.66	.57	.33	.35	.13	T	.17	.32	1.00	1.11	3.75	23.78
Greatest daily	2.22	3.41	2.19	1.85	1.66	1.53	.74	1.36	1.77	2.27	3.41	2.53	3.41

Source: Brown and Caldwell/Jones and Jones, 1979.

Table 3. ESTIMATED EVAPOTRANSPIRATION (Inches of Water)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
<u>Seattle-Tacoma Airport</u>													
Precip	4.7	4.0	3.4	2.1	1.6	1.3	0.6	0.9	1.7	3.3	4.5	5.7	33.8
PET	0.3	0.6	1.2	1.8	3.1	3.8	4.5	4.1	2.8	1.8	0.8	0.5	25.3
Ea(6)	0.3	0.6	1.2	1.8	3.0	2.9	2.0	1.6	1.9	1.8	0.8	0.5	18.4
<u>Seattle University of Washington</u>													
Precip	4.7	3.9	3.2	2.1	1.9	1.5	0.8	0.7	1.8	3.5	5.1	5.6	34.8
PET	0.5	0.7	1.2	2.0	3.1	3.8	4.6	4.2	3.0	2.0	0.9	0.6	26.6
Ea(6)	0.5	0.7	1.2	2.0	3.0	3.1	2.4	1.4	2.0	2.0	0.9	0.6	19.8

*Precipitation (Precip), Potential Evapotranspiration (PET), Actual Evapotranspiration for the 6-inch waterholding capacity soil (Ea(6))

Source: Brown and Caldwell/Jones and Jones, 1979

Temperatures

Temperatures are quite moderate in this region (Table 4), with an average annual temperature of 52°F. The growing season - the average number of days between the last frost in spring and the first autumn frost - is about 240 days. Grass continues growing slowly during mild periods throughout the winter.

The wind rose on Figure 1 shows that the wind is predominantly under 13 miles per hour (mph), (more than 82 percent of the time). Of the winds greater than 13 mph, 75 percent are from the south or southwest. Calms (0 to 3 mph) occur 22.4 percent of the time.

Topography

The airport lies just above sea level, between 9 and 18 foot elevations. The entire site is quite level, with no slopes greater than 5 percent in the areas considered for sludge application (Figure 3). An open drainage ditch along Norfolk Street and a swale in the southeast are to be excluded as application sites.

The airport's own storm drainage system completely drains the site, alleviating any concern for runoff onto neighboring

Table 4. TEMPERATURE AVERAGES AND EXTREMES (^{o}F)

Station	Data	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Seattle Boeing Field	Av. Max	45.2	49.5	54.3	61.8	68.5	73.1	78.4	77.1	71.5	62.3	52.4	47.3	61.8
	Av. Min.	31.1	33.6	36.4	40.7	46.2	51.2	54.9	54.0	49.4	42.9	35.9	33.5	42.5
	Mean	38.2	41.6	45.4	51.3	57.4	62.2	66.7	65.6	60.5	52.6	44.2	40.4	52.2
	Highest	69	70	76	85	90	99	99	100	92	82	69	67	100
	Lowest	3	4	16	28	30	37	44	43	33	24	8	11	3
Seattle City	Av. Max.	45.6	48.8	52.7	59.4	65.7	69.6	75.1	73.9	69.0	60.4	51.8	48.0	60.0
	Av. Min.	36.8	38.3	40.1	44.1	49.0	53.1	56.1	56.1	53.3	48.3	41.9	39.5	46.4
	Mean	41.2	43.6	46.4	51.8	57.4	61.4	65.6	65.0	61.2	54.4	46.9	43.8	53.2
	Highest	66	70	75	87	92	100	100	97	92	78	70	65	100
	Lowest	11	12	22	31	35	45	48	48	42	30	13	21	11
Seattle-Tacoma Airport	Av. Max.	43.6	47.0	51.3	58.2	65.6	69.9	75.6	74.6	69.3	60.3	49.6	45.9	59.2
	Av. Min.	33.0	34.5	36.2	40.1	45.3	49.7	54.1	53.6	50.5	44.4	38.1	35.7	42.9
	Mean	38.3	40.8	43.8	49.2	55.5	59.8	64.9	64.1	59.9	52.4	43.9	40.8	51.1
	Highest	61	68	71	77	93	90	97	99	89	80	65	60	99
	Lowest	12	18	23	30	33	41	46	45	39	33	23	10	10
Seattle U of W	Av. Max.	45.6	49.2	53.7	60.8	67.0	71.5	76.6	75.7	70.7	61.8	51.8	47.8	61.0
	Av. Min.	34.6	36.0	38.1	41.8	46.9	51.2	54.8	54.7	51.5	46.4	40.2	37.6	44.5
	Mean	40.1	42.6	45.9	51.3	57.0	61.4	65.7	65.2	61.1	54.1	46.0	42.7	52.8
	Highest	68	71	75	88	90	98	98	96	96	88	67	65	98
	Lowest	6	8	17	30	34	36	41	46	39	29	10	15	6

Source: Brown and Caldwell/Jones and Jones, 1979.

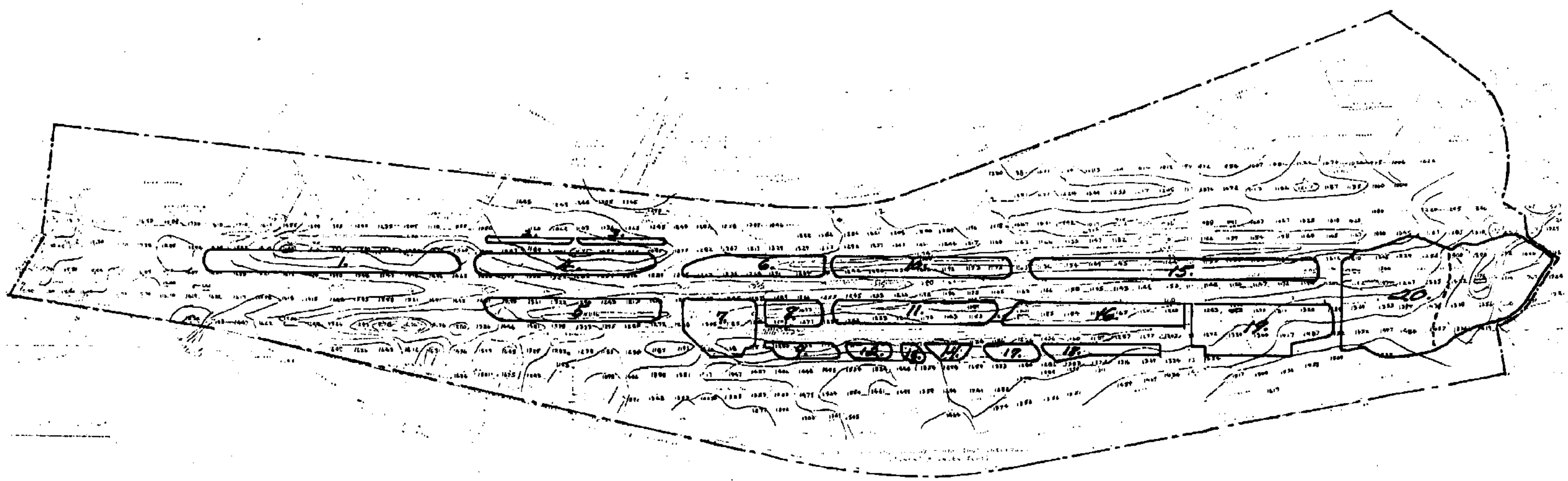


Figure 3. Airport Site Topography - One Foot Intervals (Source: K.C.I.A. Engineering Dept. 1976)

property. Overbank flooding of the Duwamish is controlled by the Army Corps of Engineers standard project flood (SPF) protection. According to a Corps spokesperson, there is so little danger of overbank flood at the airport site that, "...it probably lies outside the 500 year floodplain." (Linda Smith, personal communication).

Since enhancing the turf quality is a major objective, the present grass cover will be left in place. A vigorous grass cover is acknowledged as among the best soil protection agents for increasing infiltration and checking erosion (Brady, 1974).

Geology

The airport is located over an alluvial fill of a glacial valley. River deposited layers of a sand, or silty sand, alternate with layers of sandy silt, or clayey silt, to depths of at least 30 feet (Weber and Associates, 1980; Shannon and Wilson, 1977). The former river channel was filled by hydraulic dredging in the early 1900's. Consequently, the top 2 to 6 feet of soil consists partially of fill material (loose to dense, silty sand and gravel or silty sand) (Shannon and Wilson, 1977). Scattered organics and debris also occur in this layer.

Soils and Groundwater

Extensive alteration of the surface horizons prevents classification of this soil into a specific series. A general description of the site is available from the 1977 report by Shannon and Wilson and the 1980 Paul Weber study.

For most of the site, a layer of grass roots extends to 4 inches below the surface; where the grass has been worn away, the mineral soil is exposed. The surface, 2 to 6 feet deep, is loose to dense silty sand or silty sand and gravel. Infiltration through this type of material should be greater than 2 inches per hour (Hough, 1968). Where the soil is compacted, infiltration rates will be less rapid. However, with the establishment of a grass cover, surface runoff (occurring during periods of saturated surface soil) will be minimal for all but the heaviest prolonged winter rains. Application at the beginning of the dry season (April), will limit loss by runoff and a grass buffer strip left between sludge applied areas and the surface drains will further mitigate surface flows.

Underlying the surface layer is 3 to 7 feet of relatively impermeable clayey silt. The mottled coloring of the silt is indicative of alternate wet (reducing) and dry (oxidizing) periods. Some seepage of groundwater above this layer was discovered during subsurface investigations. Apparently, this silty layer collects the water moving through the porous surface layers.

A water bearing sand layer lies beneath the silt layer. The groundwater table is confined by the overlying silt and is under some pressure. Piezometric water levels rise to within 5 feet of the surface and are probably controlled by tides (Weber, 1980).

Groundwater Quality and Use

The quality of the groundwater in the area has not been assessed. Seattle city water is used by all residences and businesses in the vicinity. The State Department of Ecology has identified only four users of local water (Figure 4).

They are:

Map #13737 (1956)	- Liquid Carbonic Corporation 5021 Colorado Street
Use	- Industrial
Source	- Duwamish River

Map #S1210199	- Kaiser Gypsum Company, Inc.
Use	- Industrial
Source	- Duwamish River

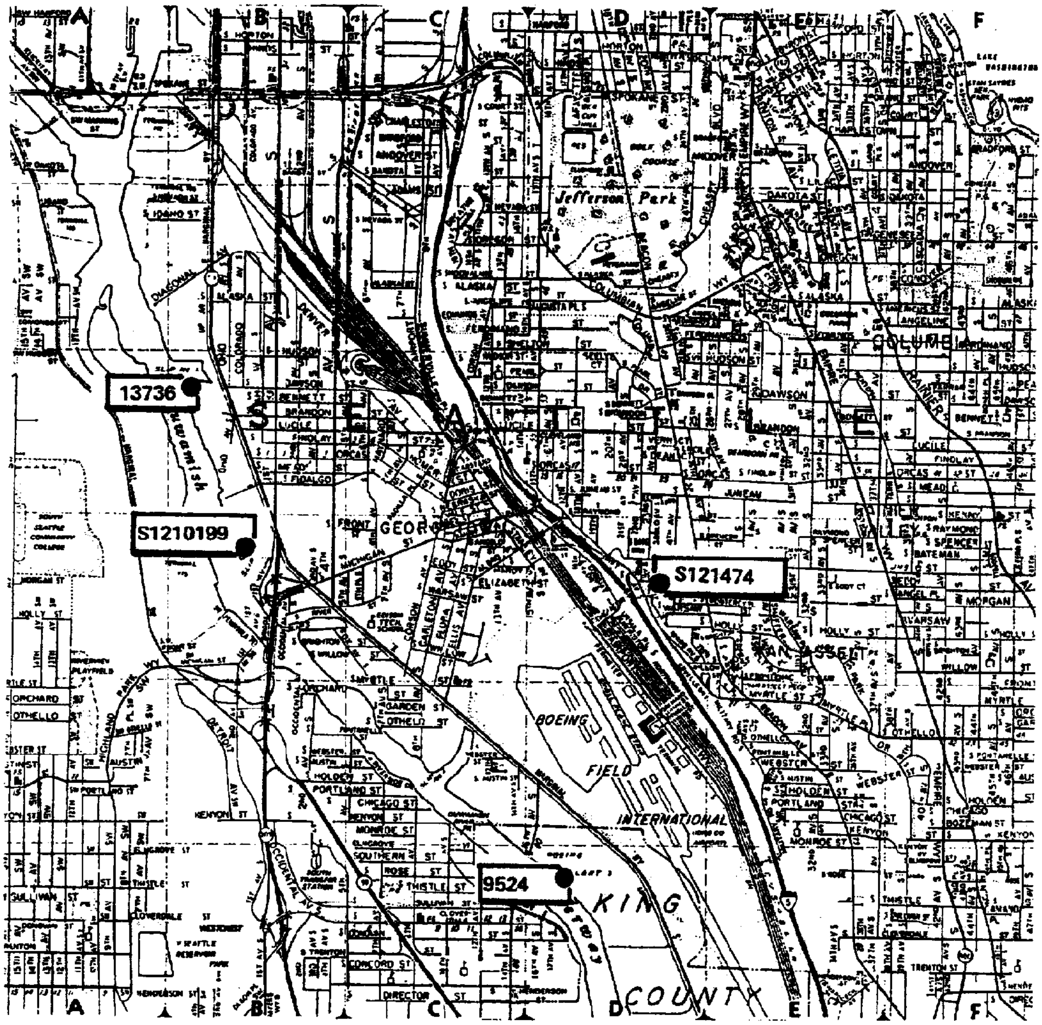


Figure 4. Water Rights in Airport Vicinity

Map #9524 (1951) - The Boeing Company

Use - Industrial

Source - Duwamish River

Map #S121474 - Maurice Hein

6428 23rd Avenue South

Use - Irrigation

Source - Unnamed stream above airport

None of these users will be affected by the proposed project, since they are either above the airport or will be using water that has been considerably diluted by the Duwamish River.

Wells. No wells are known to exist in the area. The presence of a saltwater lens in the Duwamish, extending beyond the airport (Brown and Caldwell/Jones and Jones, 1979), suggests that groundwater in the area would be unsuited for future domestic use. Infiltration of saltwater, as groundwater is removed, has caused concern in several coastal cities.

Domestic Systems. Pipes carrying domestic water run beneath the site proposed for application. These cast iron pipes carry a static charge of 130 psi, dropping to a minimum of 40 psi under heavy use. Groundwater infiltration should not be a factor under these conditions.

Receiving Water

Storm Drainage System. Water is carried from the airport grounds by an extensive storm drainage system. Two pumping stations raise the water from a 20 foot depth to the entrance of the outfall pipes at a 3 to 4 foot depth. The northwest pumping station has a capacity of 60 cfs and the southwest station is designed for 80 cfs. A third gravity fed outfall along the south end of the airport is designed for 13 cfs maximum. Except for an oil separation unit of unknown efficiency, this drainage passes untreated to four outfalls on the Duwamish River.

Topography at Plots. Each grassy plot between the runways is gently sloped (less than a 5% grade) to a surface drain in the center. No evidence of either rill or gully erosion (indicative of overland flow) was observed. However, even after several days without precipitation, an appreciable (although unmeasured) amount of flow was noticed at the bottom of these drains. An airport official explained that some water from a Boeing Company cooling system enters the storm system via a 3 inch pipe. This was not enough, however, to generate the considerable rate observed. Groundwater infiltration through cracks and joints in the concrete collection pipe probably accounts for this flow, given the porous nature of the soil and the depth of the pipe. Thus, it is expected that much of the flow from the airport to the Duwamish outfall is first filtered through the soil. With careful application, all stormwater reaching sludge treated areas will filter through grass and soil before collection and outfall.

Duwamish River. The Duwamish River has received careful study by Metro and others (Metro, 1980). The tide remains a strong influence near the airport, and saltwater can be found far up river, particularly during summer low flow periods. Since the water is not used for human consumption, primary concern centers around toxicity to fish - especially salmonids. The river may be considered sensitive to inputs of organic and heavy metal toxicants, ammonia, phosphates and other compounds that might contribute to chemical and oxygen demand.

Security

Access to the runway area is strictly controlled by a twenty-four hour security patrol.

Bird Hazard to Aircraft

The FAA has placed the King County Airport into the second of three priority classes for potential bird hazards. This classification recognizes that the airport has a known bird hazard, but that this hazard is not associated with a solid waste or sludge disposal facility (EPA, 1980). No increased attraction to the airport was observed after sludge applications in 1976 and 1980. Airport officials are alert for bird populations and dispatch personnel to disperse any large gatherings. Continued surveillance by the airport will be necessary.

SLUDGE MANAGEMENT CONSIDERATIONS

Sludge Characteristics

Sludge is the residue from municipal sewage treatment. In Seattle, this process includes anaerobic digestion to reduce the organic content and the total mass. This is also a process to significantly reduce pathogens as defined by Federal Regulation 40 CFR 257. This material is then centrifuged (dewatered) to further reduce the mass to be transported. The resulting dewatered sludge has a solids content of about 18 percent and a paste-like consistency.

Detailed chemical characteristics of sludge from Seattle's West Point treatment plant are reported by Edmonds and Cole (1977, 1980). Most of the dry weight of sludge is inert, inorganic material. Only about 25 percent of the dry weight is organic. Nitrogen concentration is primarily in the organic and ammonia form until nitrification (oxidation) proceeds after application. Phosphorous and other nutrients are also present in concentrations higher than usually found in Western Washington soils.

The concentrations of heavy metals (e.g., cadmium (Cd), lead (Pb), copper (Cu)) are high enough to place some limitations on application of this sludge to food crops (Federal Regulation 40 CFR 257). Since this project does not include the food chain, metal concentrations are not an issue.

Method of Application

Surface application in a thin layer is the preferred option for several positive reasons:

1. It least disrupts the established grass cover, thus reducing the surface storm flow and increasing the nutrient uptake immediately.

2. It causes rapid drying, which avoids anaerobic odors, hastens aerobic decomposition and further increases retention of stormwater.

3. It results in the lowest possible nitrogen loading rate while enhancing the greatest turf area.

4. It is the quickest method of application, causing minimal interruption of airport operations.

5. It requires the least equipment and manpower.

Also, since electrical conduits for lighting and communication systems are buried throughout the site, incorporation of sludge into the soil and subsurface injection are eliminated as management alternatives.

Environmental Effects of Sludge

Data from five years of research by the University of Washington (1973 to 1979) show that only nitrate has leached from sludge treated areas in any significant concentrations (Edmonds and Cole, 1980). Cationic nutrients (such as ammonium ion (NH^+_4) and potassium ion (K^+)), metals and microbial populations are retained in the surface horizons of the porous sandy and gravelly soils studied. Similar results have been reported by Zenz et al. (1976) for sludge applied in Illinois.

Input of the oxidized forms of nitrogen should place no further oxygen demand or have any toxic effect on the river ecosystem (Wetzel, 1975).

The effect of NO^{-}_{3} as a nutrient addition to the river would be most crucial during the warm weather and low flow months of July and August. Leachate data from the University of Washington demonstration project show that both low N concentrations and low throughflow, from sites amended with sludge, occur during these months (Edmonds and Cole, 1980). The soil water deficit (Table 3) and high nutrient uptake by the grass would further minimize the loss of NO^{-}_{3} to the Duwamish during the summer months.

Data from 1979 and 1980 for sampling sites upstream (East Marginal Way Bridge) and downstream (16th Avenue South Bridge), show no significant differences in nitrate concentrations between the sites. In fact, nitrite-nitrate (NO_2-NO_3) concentrations were higher upstream (.713 and .581 mg/liter in May and August, 1980) than downstream (.614 and .573 mg/liter for the same sampling days) after 60 dry tons of sludge were applied to the airport in April, 1980.

These data do not eliminate concern for potential input to the river from this project, but they do put the magnitude of the input into perspective.

Nitrogen Budget

Researchers at the University of Washington have examined the fate of nitrogen in dewatered sludge for various soil application rates. After one year, over 66 percent of the initial N content of a 5 cm (2 inch) treatment remained associated with the sludge (Mayer, 1980). Nitrogen was released from the sludge layer at a slightly greater rate from a 10 cm (4 inch) treatment (Mayer, 1980; Vogt et al., 1981). Vogt showed that almost all of this release involved volatilization of ammonia or nitrogen gas; only 1.3 percent of the initial N moved from the sludge into the surface of the soil. Other researchers have also observed high volatilization rates of N from anaerobically digested sludge applied to land (Beauchamp et al., 1978).

The N that is released into the atmosphere has no further environmental impact. Nitrogen that is released into the soil becomes available for uptake by plants. For grass, the annual uptake rate is between 150 and 300 lbs. N per acre (EPA 1980).

The N content of Metro's sludge varies from about 2.5 percent to 4.5 percent of the dry weight, with most researchers reporting concentrations near 3 percent (Edmonds and Cole, 1977, 1980). Assuming that the sludge applied to the airport averages 3.5 percent N, the loading rate of a one inch application (equivalent to 20 dry tons of sludge per acre) would be 1,400 lbs. N/acre. Using a conservative estimate, 1.5 percent of this total N may be released to the soil. Thus, only 21 lbs. N/acre would enter the rooting zone of the turf per year.

This value can be compared with an EPA (1978) estimate, that 1.7 lbs. N/per ton of sludge will be released during the first year, with the rate decreasing in following years. This release rate does not account for application rate or method, but still amounts to only 34 lbs. N/acre for a one inch sludge application.

Both of these estimates are far less than the annual uptake rate of grass. All of the N becoming available to the plants is expected to be assimilated, and leaching losses to the ground- or surface water should be negligible.

Odors and Aerosols

Research conducted by the University of Washington shows that rapid drying occurs in 5 cm (2 inches) sludge treatments applied to the surface of an open area during the summer months (Mayer, 1980). The proposed 1 inch treatment will dry and oxidize even more rapidly, eliminating odors associated with anaerobic conditions and causing populations of potentially pathogenic bacteria to decrease sharply.

The surface tension of sludge prevents microbial populations from becoming airborne under most conditions (Edmonds and Littke, 1978). When the surface of the sludge becomes very dry, spores may be carried into the air with dust particles. A grass cover should prevent the sludge from becoming too dry and also increase the boundary layer to limit the effect of the wind on the sludge surface. Strong winds are not common at the airport site. Only takeoffs of Boeing 747's have been observed to affect the ground beyond the sides of the runways (Jeff Winter, airport engineer, personal communication). This occurs primarily at the rotation point (as the front landing gear leaves the ground) near the center of the runway. The number of 747 takeoffs is less than one per day.

Concern for aerosols from the project is largely limited to one event per day during prolonged dry periods before pathogen populations have died off. The risks associated with aerosol emissions from sewage treatment plants have been addressed at a recent symposium (EPA, December, 1980). These aerosols contain greater populations than Edmonds and Littke (1978) found emanating from the surface of sludge. The conclusions of four separate studies (Fannin et al., 1980; Johnson et al., 1980; Camann et al., 1980; Northrop et al., 1980) and the general concensus of the symposium were that no evidence of infectious effects are associated with sewage treatment aerosols, despite elevated aerosol bacteria levels. These studies included neighborhoods and schools immediately adjacent to the treatment facilities. Furthermore, no effect of the April, 1980, trial at the airport site has been reported. The public health risk from aerosols from this project appears minimal.

METHODOLOGY

WORKPLAN

Starting Schedule

For optimal drying and promotion of grass growth, application should be initiated as soon after the winter rainy period as possible. Historically, April has been the beginning of the dry season. Inclement weather would postpone the first application.

Agreements between Metro and the airport must be settled before final implementation. One month of background sampling will be conducted before application.

Site Preparation and Operation

Each site must be inspected by an airport official and a Metro representative familar with sludge truck operations. Each site will be flagged in such a way, that the driver can clearly identify the location of each delivery. All obstructions, such as light standards, will also be indicated. A buffer strip around each storm drain will be clearly marked so that no sludge is applied within five feet of any storm drain. The Metro representative will be responsible for insuring that each area's delivery is properly applied. The sludge should be spread to a 1 inch depth on the same day as applied. This is necessary to avoid odors, maintain the turf and prevent surface runoff from a thick application of sludge.

The April, 1980 trial showed that application from the transport trucks directly onto the site, followed by spreading with a road grader (owned and operated by King County International Airport), resulted in a uniform 1 inch application. This rate was the least possible for the road grader without uprooting the grass. This application still allowed the grass to emerge above the sludge. The rate of 1 inch per acre translates to 20 dry tons of dewatered sludge per acre.

Delivery to the site will be limited both by daylight, weekday operations and by limitations of the equipment. All trucks will be scheduled so that they can be escorted onto the runways by airport security. If weather (intense or prolonged rain) interferes with the application procedure, application will be halted until proper conditions return.

The airport has indicated that they can handle up to five loads per day (three in the morning and two in the afternoon). This tentative schedule can be adjusted as a clearer picture of equipment and time constraints develops. At a rate of 25 loads per week (4 dry tons per load), the entire 108 acre application (at 20 tons/acre) will be completed in 22 weeks. So, if the schedule is delayed so that application may extend beyond August, a postponement of part of the project until the following dry season should be considered.

Monitoring

A two year monitoring program is planned for the King County International Airport project. The monitoring includes a thorough characterization of the sludge as it leaves the treatment plant. This coincides with an intensive in-plant sampling effort under a DOE grant.

In cooperation with airport officials, an accessible site will be selected as a control (no sludge application). A month or more before application, two soil samples from this site and two from a site to be treated with sludge will be analyzed. The parameters are presented in Table 5. After sludge has been applied, four samples (one control and three sludge samples) will be taken on a bi-monthly basis.

Four water samples will be taken concurrently with the sludge and soil samples. The same parameters will be analyzed. Water samples can conveniently be taken at nearby catch

Table 5. **METRO SLUDGE MONITORING PROGRAM**

SAMPLING PARAMETERS

Group 1: Metals, Water Quality

Total P	Cadmium	Selenium	Barium
Potassium	Lead	Boron	
Nitrates	Mercury	Chromium	
NH_3-N	Arsenic	Copper	
Organic Nitrogen	Molybdenum	Nickel	
Volatile Solids	Zinc	Silver	

Group 2: Pathogenic Organisms

Indicator organisms
- fecal coliforms
- fecal streptococci

Enteric bacteria
- salmonella
- Yersinia enterocolitica
- mycobacteria
- One additional (to be determined, depending on initial screen)

Enteric viruses
- Polio 1, 2, 3
- Coxsackie (A & B)
- ECHO
- Adeno
- Reo

Parasites
- Ascaris lumbricoides (round worm)
- Giardia lamblia

Group 3: Toxic Organics

PCB		
Chlordane	Endrin	2, 4, 5-TP
Dieldrin	Lindane	Silvex
DDT	Methoxychlor	
Aldrin	Toxaphene	
	2, 4-D	

basins. Groundwater wells are unnecessary and undesirable at this site. For a month before application, all four water samples (two samples at each station) will be taken to establish background levels. The station in the site unaffected by sludge will continue to be used as a control.

The data will be used to identify any environmental and public health concern.

King County Airport will continue to be responsible for bird hazard monitoring. The airport will obtain any required formal approval for this project from the FAA, so that Metro will not be liable for safety problems related to bird activity.

Reporting Procedure

Progress reports will be sent on a bi-monthly basis to Duaine Moe (Superintendent of Maintenance) and Jack Frazelle (Assistant Airport Manager). The reports will include areas completed, application rate, monitoring results (synopsis) and other pertinent information.

CONCLUSIONS

Previous experience at the King County Airport indicates that sludge application noticeably improves the turf. Potential effects on surface and groundwater, odors, aerosols and other health and safety considerations have been thoroughly discussed. A 1 inch surface application to the grass around the runways should result in no negative impact on the environment.

An intensive monitoring effort will quantify a complete range of environmental parameters in the sludge, soil and drainage water.

RECOMMENDATIONS

Implementation of the project as described should begin in April, 1981, after background samples have been taken. Sludge should be applied to the site selected for monitoring and application should continue in areas designated in agreement with airport officials. The delivery schedule will vary with the availability of airport personnel to apply the sludge. Operations will be halted during periods of intense or prolonged rainfall and be resumed during dry weather.

BIBLIOGRAPHY

Beauchamp, E. G., G. E. Kidd and G. Thurtell. 1978. Ammonia volatiliation from sewage sludge applied in the field. J. Environ. Qual. 7:141-146.

Brady, N. C. 1974. The Nature and Properties of Soils. Macmillan, New York.

Brown and Caldwell/Jones and Jones. 1979. Wastewater management study, Lake Washington/Green River basins. Tech. Memorandum No. 2: Existing Study Area. Metro, Seattle, Washington.

Camann, D. E., D. E. Johnson, H. J. Harding and C. A. Sorber. 1980. Wastewater aerosol and school attendance monitoring at an advanced wastewater treatment facility. pp 160-179 In: Wastewater aerosols and disease. H. Pahren and W. Jakubowski (eds.) EPA-600/9-80-028, Cincinnati, Ohio.

Edmonds, R. J. and D. W. Cole (eds.) 1977. Use of dewatered sludge as an amendment for forest growth. Vol. II. Center for Ecosystem Studies, Seattle, Washington.

Edmonds, R. J. and D. W. Cole (eds.) 1980. Use of dewatered sludge as an amendment for forest growth. Vol. III. Center for Ecosystem Studies, Seattle, Washington.

Edmonds, R. J. and W. Littke. 1978. Coliform aerosols generated from the surface of dewatered sludge applied to a forest clearcut. J. Appl. and Environ. Microbiol. 36:972-974.

EPA. 1978. Sludge treatment and disposal. Vol. 2: Sludge disposal. EPA 625/4-78-012. Cincinnati, Ohio. 1550.

EPA. 1980. Classifying solid waste disposal facilities. SW-282, EPA, Washington, D.C.

Fannin, K. F., K. W. Cochran, D. E. Lamphiear and A. S. Monto. 1980. Acute illness differences with regard to distance from the Tecumseh, Michigan, Wastewater treatment Plant. p. 117-135 In: Wastewater aerosols and disease. H. Pahren and W. Jakubowski (eds.) EPA-600/9-80-028, Cincinnati, Ohio.

Hough, G. K. 1969. Basic Soils Engineering. Ronald Press, New York.

Johnson, D. E., D. E. Camann and J. W. Register. 1980. Health effects from wastewater aerosols at a new-activated sludge plant: John Egan Plant, Schaumburg, Illinois. p. 136-159 In: Wastewater aerosols and disease. H. Pahren and W. Jakubowski (eds.) EPA-600/9-80-028, Cincinnati, Ohio.

Mayer, K. P. 1980. Decomposition of dewatered sludge applied to a forest soil. M.S. thesis, University of Washington.

Metro. 1980. A guide to water quality data and technical information. Seattle, Washington.

Northrop, R. L., B. Carnow, R. Wadden and S. Rosenberg. 1980. Health effects of aerosols emitted from an activated sludge plant. p. 198-227. In: Wastewater aerosols and disease. H. Pahren and W. Jakubowske (eds.). EPA-600/9-80-028, Cincinnati, Ohio.

Riekerk, H. 1978. The behavior of nutrient elements added to a forest soil with sewage sludge. Soil Sci. Soc. Am. J. 47:810-816.

Shannon and Wilson, Inc. 1977. Subsurface exploration and testing, west taxiway extension, King County International Airport, Seattle, Washington.

Vogt, K., R. L. Edmonds and D. J. Vogt. 1981. Nitrate leaching in soils after sludge application. In: Proceedings of municipal sewage waste application to lands in the Pacific Northwest. C. Bledsoe (ed.), University of Washington (in press).

Weber and Associates. 1980. Subsurface investigation for King County Airport hangers. Seattle, Washington.

Wetzel, R. G. 1975. Limnology. W. B. Saunder, New York.

Zenz, D. R., J. R. Peterson, D. L. Brooman and C. Jue-Hing. 1976. Environmental impacts of land application of sludge. JWPCF 48(10):2332-2342.

APPENDIX

APPENDIX I - GLOSSARY

GLOSSARY

Aerosol - suspension of fine solid or liquid particles in gas (mist or fog)

Enteric - intestinal (viruses)

Rill - channel made by a small stream

Swale - low lying or depressed and often wet stretch of land.

Wind Rose - A diagram showing the relative frequency or frequency and strength of winds from different directions for a given place